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The views expressed in this paper are those of the authors.
No responsibility for them should be attributed to the Bank of Canada.

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Abstract

The authors contrast the impact of two sources of information flow on the volatility of prices, trading activity, and liquidity in the brokered interdealer market for Government of Canada bonds. Liquidity varies with the amount of asymmetric information in the market, and order flow plays a central role in the processing of information. The authors find a two-stage adjustment process in the period before and after a scheduled 8:30 a.m. macroeconomic news announcement that is similar to the adjustment process documented by Fleming and Remolona (1999) for the U.S. Treasury market. They contrast these dynamics with the adjustment that occurs around a Government of Canada bond auction. Results are somewhat inconsistent with the patterns observed around macroeconomic news events, but are explained by theory.

JEL classification: G14
Bank classification: Financial markets; Market structure and pricing; Debt management

Résumé

Les auteurs comparent l'incidence qu'ont les informations provenant de deux sources distinctes sur la volatilité des cours, l'activité et la liquidité dans le marché du courtage intermédiaire d'obligations du gouvernement canadien. La liquidité varie selon le degré d'asymétrie de l'information sur le marché, et les flux d'ordres jouent un rôle central dans le traitement de l'information. Les auteurs constatent qu'un processus d'ajustement en deux étapes a lieu durant la période qui précède et qui suit l'annonce prévue, à 8 h 30, d'une nouvelle macroéconomique, et que ce processus s'apparente à celui que décrivent Fleming et Remolona (1999) relativement au marché des titres du Trésor américain. Ils comparent cette dynamique avec l'ajustement qui s'opère avant et après les adjudications d'obligations du gouvernement canadien. Les résultats ne cadrent pas tout à fait avec les tendances observées lors de la publication de nouvelles macroéconomiques, mais ils trouvent leur explication dans la théorie.

Classification JEL : G14
Classification de la Banque : Marchés financiers; Structure de marché et fixation des prix; Gestion de la dette

1. Introduction

Efficient and liquid government securities markets are often viewed as important to a country's economic well-being because they perform a number of key functions. For example, given their virtually default-free nature, government securities are used as benchmarks for the pricing and hedging of other fixed-income securities. In addition, market participants use government securities to speculate on the course of interest rates, because they can buy and sell the securities quickly and with minimal transaction costs. One important feature of government debt markets is the extent to which they are driven by public news, and, in particular, macroeconomic news. The information in scheduled macroeconomic news releases is scrutinized by the market, whose participants seek to determine the future cost of capital. News releases, such as those associated with changes in employment, retail sales, and the consumer price index (CPI), have been found to affect the term structure of interest rates.[1]

It could take some time before news is fully reflected in prices and yields if investors have differing abilities (e.g., different models and experience) in processing information, or if they have different interpretations of the news. One way in which markets process information is by observing order flow, sometimes quantified as buyer- less seller-initiated trades. Dealers, who supply liquidity in government securities markets by executing transactions against their own inventory of bonds, observe part of the overall order flow in the market. Order flow reflects dispersed information on participants' expectations about future fundamentals, and their interpretation of macroeconomic news. Consequently, dealers will initiate trades when their private bond valuations, conditioned on their private order-flow information, differ from market prices.

Macroeconomic news announcements are not the only direct source of information that affects prices and yields in government securities markets. Brandt and Kavajecz (2002) find evidence that a large part of the variability in yields occurs outside the release of public information. Specifically, order flow is important because it aggregates the information in trades. Trades contain little bits of information about fundamentals in the economy, including information about the cost of capital.[2] It is important to recognize that individual traders may not consider themselves to have superior information. But if their trades are correlated with macroeconomic variables, then the order flow collected by dealers conveys incremental information about the

1. See Gravelle and Moessner (2001) for details on which macroeconomic news releases in Canada and the United States affect interest rates.
2. Evans and Lyons (2004) examine how information from the real side of the economy is aggregated through trades in a dynamic general-equilibrium model.

economy. If dealers use order-flow information in their speculative and hedging decisions, it will eventually be incorporated into prices and yields. Brandt and Kavajecz (2002) find order-flow imbalances account for up to 21 per cent of the day-to-day variation in yields on days without major macroeconomic announcements. We focus on how government securities markets behave as information is released and processed.

Making use of high-frequency data, we examine the role of information in government securities markets by exploring the impact that Canadian and U.S. macroeconomic news announcements, and the release of the results of a Government of Canada bond auction, have on trading activity, price volatility, and liquidity in secondary markets. To our knowledge, this is the first study to contrast price and trade dynamics around bond auctions and macroeconomic news releases.

The capture of trade and quote information during the period surrounding a government securities auction gives us a unique opportunity to analyze how order flow unrelated to macroeconomic news releases is processed by the market. In the Government of Canada primary market, government securities dealers bid for themselves and submit bids on behalf of their clients. The bids of a dealer's clients are received over a short amount of time, and are the dealer's private information. They reflect part of the overall order flow in the market. An understanding of price and trade dynamics around the auction will in turn afford an understanding of how the market behaves over longer periods of time as order-flow information unrelated to macroeconomic news is revealed.

The type of information revealed around a bond auction differs from that of a macroeconomic news announcement, and should have a different impact on price levels. In this paper, we are not concerned with the overall change in prices subsequent to a news release, but the behaviour of prices and trades before and after the release. The pattern in prices and trades that we attempt to uncover will depend in part on how private information is revealed in the market. Market participants will form an expectation about a macroeconomic news announcement prior to its release. Expectations will reflect the participants' own models and the analysis of other participants who monitor and analyze the economy. Private information exists prior to the release if participants believe that they have a superior forecast, and if they want to keep their forecasts private in the hope of trading on their differential view.

The actual macroeconomic news announcement is public information that affects prices before anyone can trade on it. After the announcement is made, private information may again exist if participants differ on how to interpret the macroeconomic news. Green (2004) finds that information asymmetry rises in the wake of an important macroeconomic news announcement.

Over time, private information in the market will dissipate once it is reflected in trades and order flow, and then subsequently in prices.

In comparison, before the results of a securities auction are released, dealers will have private information about its results if they have participated in the auction either on their own behalf or on behalf of their clients. Once the results of the auction are released, there is little scope for private information about prices or yields. In this paper, we attempt to characterize the behaviour of prices and trades around these two types of news releases. An event-study approach is used because standard time-series techniques are not well suited. In particular, a controlled experiment can be performed by comparing dynamics on days with and without a release.[3]

The measurement and tracking of liquidity is relevant to those who transact in the market. A liquid financial market is one where participants can rapidly execute large transactions with only a small impact on prices.[4] Traditional market microstructure models predict that liquidity will deteriorate around the release of an information event and return to normal afterwards.[5] Kim and Verrecchia (1994) argue that, if informed traders possess an informational advantage after an event, liquidity will remain low as long as the informed traders maintain their interpretation advantage. Volatility may also increase temporarily as investors adjust their beliefs. After an adjustment period, liquidity will revert to normal, and volatility will subside. This may coincide with a period of abnormally high trading activity as traders rebalance their portfolios. Given the many dimensions of liquidity, we use a number of measures to calculate it.

Why should we care about liquidity in government securities markets? Research has indicated that market liquidity has a positive, first-order impact on asset returns (e.g., Amihud, Mendelson, and Lauterbach 1997). Goldreich, Hanke, and Nath (2003) explore liquidity by comparing fixed-income securities that differ only in whether they are "on-the-run" or "off-the-run." They find that more-liquid securities are priced higher, but the difference depends on the amount of expected future liquidity over its remaining lifetime, rather than just its current liquidity. Ellul and Pagano (2002) focus on liquidity to shed light on a long-standing puzzle in the finance literature. They find that underpricing of initial public offerings in the equity market can be explained by taking into account investors' expectations of future liquidity, and by the uncertainty about the level of

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3. MacKinlay (1997) provides a survey of the event study methodology.
4. Market liquidity can be defined across four dimensions: immediacy, depth, width (bid/ask spread), and resiliency. Immediacy refers to the speed with which a trade of a given size at a given cost is completed. Depth refers to the maximal size of a trade for any given bid/ask spread. Width refers to the costs of providing liquidity. Resiliency refers to how quickly prices revert to original (or fundamental) levels after a large transaction.
5. See Admati and Pfleiderer (1988) and O'Hara (1995).

liquidity when shares start trading on the market. The less liquid shares are expected to be and the less predictable their liquidity, the larger will be the required underpricing. Findings suggest that expected aftermarket liquidity and liquidity risk are important determinants of initial public offering (IPO) underpricing. Around the world, government debt managers are keen to foster liquidity to minimize the cost of public funds.

Studies of intraday conditions in the U.S. Treasury market have revealed a great deal about its quality.[6] In particular, the studies have sought to measure the average level of liquidity in the market, characterize how liquidity changes over time and in periods of stress, and examine how the government yield curve adjusts to new information. Overall, the results of the studies suggest that the U.S. Treasury market is extremely liquid, and that it incorporates relevant news into prices and yields nearly instantaneously.

Fleming and Remolona (1999, henceforth referred to as F&R) find that U.S. Treasury markets react to public macroeconomic information with a sharp reduction in liquidity combined with rapid price changes as information is absorbed, and then a subsequent surge in trading activity as participants trade on their differing views regarding the interpretation of the new information. Balduzzi, Elton, and Green (2001) also investigate the effects of scheduled macroeconomic announcements on liquidity using U.S. Treasury data. Using a larger set of new announcements, their results confirm the findings of F&R. They find that, in the aftermath of an announcement, there is a significant and persistent increase in volatility and trading volume, and that bid/ask spreads widen at the time of the announcement but then revert to normal after 5 to 15 minutes. The widening of the bid/ask spreads for up to 15 minutes after the announcement suggests that, during a second phase, both the increased levels of volatility and volume are partly driven by informed trading.

It may be tempting to assume that Canadian government securities markets behave in a comparable manner, given the similar trading structure in the two markets. Most importantly, trading in both markets takes place in a continuous, over-the-counter, competitive multidealer market.[7] Such an assumption may not be wise. One important difference is the size of the U.S. Treasury market. It dwarfs Canada's both in terms of the value of securities outstanding and average trading volumes. The outstanding value of marketable debt issued in the Government of Canada securities and U.S. Treasury market at the end of December 2003 was $373 billion and

6. For example: Babbel et al. (2003), Balduzzi, Elton, and Green (2001), Boni and Leach (2002), Brandt and Kavajecz (2002), Cohen and Shin (2003), Fleming (1997, 2002, 2003), Fleming and Remolona (1999), Fleming and Sarkar (1999), Furfine and Remolona (2001), Goldreich, Hanke, and Nath (2003), and Green (2004).
7. Gravelle (1999) provides a detailed discussion of the similarities and differences in the two markets.

$3,399 billion, respectively.[8] Even more bewildering, average daily trading volumes for Canadian and U.S. marketable government securities was $22.4 and $433.5 billion, respectively, in 2003.[9] Differences in the size of the markets themselves may be a factor generating differences in liquidity dynamics. Furthermore, a whole set of other factors—such as the number, or concentration, of government securities dealers, the method in which securities are auctioned, or even the amount of capital dealing financial institutions allocate to managing U.S. Treasuries and Government of Canada securities risk—necessitate a separate and detailed analysis of how Canadian government securities markets behave.

This paper extends the existing literature by investigating the high-frequency market conditions that surround macroeconomic news releases and government securities auctions. We do not explicitly analyze the price-discovery process of government bond markets. In particular, our analysis is not aimed at evaluating competing models of interest rate determination by examining the effects of news on yields. We focus on measuring liquidity surrounding macroeconomic news announcements and government bond auctions. The effects that scheduled macroeconomic news releases and securities auctions have on price volatility, bid/ask spreads, trading volumes, trade and quote activity, proportion of trades that undergo expansion, and price-impact coefficients are documented. Trades often go through an expansion process in which a broker mediates an increase in trade size beyond the amount quoted. The price-impact coefficient measures how much prices adjust to trades, or, more specifically, to order flow. Price-impact coefficients can be used to characterize liquidity because liquid markets accommodate trades with the least impact on prices. Our empirical analysis focuses on the benchmark (or on-the-run) 2-, 5-, 10-, and 30-year Government of Canada notes. We examine anonymous interdealer trades conducted through brokers.

In the case of 8:30 a.m. macroeconomic news announcements, we observe a two-stage adjustment to public information that is consistent with both dealer inventory control and asymmetric information interpretations of market liquidity, and similar to the findings by F&R. In the first stage, the 5-minute intervals before and after an announcement, bid/ask spreads widen and trading activity increases moderately. In an extended second stage, price volatility, trading volumes, and trade and quote activity increase to higher-than-normal levels following an 8:30 a.m. macroeconomic release, with significant effects persisting in some cases up to half an hour following the event. We also document a third stage: after an hour, we observe a surge in liquidity as price-impact coefficients fall dramatically. Enough time may have elapsed that little private

8. Par value of total bonds and treasury bills, not including Real Return Bonds.
9. Source: Federal Reserve Bank of New York and Investment Dealers Association of Canada. The data exclude repos.

information is left in the market, providing an opportunity for uninformed traders to rebalance their portfolios. Overall, the trade and price dynamics that we document suggest that the Canadian government securities market reacts to macroeconomic news in a manner that is consistent with theoretical predictions and U.S. evidence.

We find that periods that precede government bond auction cut-off times are associated with higher-than-normal trade and quote activity and volumes, and lower bid/ask spreads for each of the benchmark bonds. While bid/ask spreads widen in the period immediately before and after the release of the auction results, volatility falls. In a second stage, trading volumes, trade and quote frequencies, and price-impact coefficients are all larger than normal, because investors adjust their beliefs with information from the auction results. These results are somewhat inconsistent with the patterns observed around macroeconomic news events, but are explained by theory.

The remainder of the paper is organized as follows. Section 2 describes some institutional characteristics of the Government of Canada securities market. Theoretical predictions of market microstructure models are laid out formally in section 3. Sections 4, 5, and 6 describe the events and transaction-level data, the liquidity measures, and our statistical methodology, respectively. Section 7 discusses the results of the paper, and how they compare with those of Fleming and Remolona (1999) and theoretical predictions. Section 8 concludes. An appendix provides details on the statistical tests utilized in the paper.

2. The Government of Canada Securities Market

The market for Government of Canada securities is the largest fixed-income market in Canada, with some $256 billion in bonds[10] and $117 billion in treasury bills outstanding as of December 2003. Like most sovereign securities markets, the market for Government of Canada securities is primarily a wholesale, institutional market, where a number of professional participants[11] conduct very large trades, often in excess of $25 or $50 million, on a relatively infrequent basis. The market is generally described as being divided into the primary market, where Government of Canada securities are sold through auctions, and the secondary market.

In the primary market, the Bank of Canada conducts regular auctions of securities on behalf of the Department of Finance according to a pre-announced calendar. A group of dealers known as government securities dealers (GSDs) is granted direct access to bid in discriminatory price

10. Par value, not including Real Return Bonds.
11. Professional participants include securities dealers, pension funds, investment managers, insurance companies, and mutual funds.

auctions. One key difference between GSDs and customers in the auction is that GSDs submit bids on their account, whereas customers participate by submitting their bids through one or more GSDs.

Over the past decade, the government has supported large benchmark issues, a regular and transparent issuance calendar for 2-, 5-, 10-, and 30-year bonds, and common coupon payment dates. The target sizes of these benchmark issues have been increased to improve the liquidity of each issue. To increase the depth of the market, the Department of Finance and the Bank of Canada auction off the same bond repeatedly. This implies that a bond does not achieve its so-called "on-the-run" liquidity status as the most liquid security in its maturity class until its accumulated size nears that of the old benchmark (usually on its second-to-last or last reopening). A time schedule of the auctions is provided to the public at the beginning of the year so that market participants know in advance whether and when the bond on auction will be reopened.

The resale market for government securities is referred to as the secondary market. Most transactions take place between 7 a.m. and 5 p.m. Dealers in the market, usually representing financial institutions, commit themselves to trade continuously in the market by posting a bid and an ask price for each government security. The secondary market can be decomposed into two markets: the interdealer market and the customer-dealer market. In the customer-dealer market, institutional investors trade with dealers on a bilateral over-the-counter basis over the telephone, with the result of these transactions known only to the two counterparties who participate in the transaction.[12] The interdealer market operates partially on a direct bilateral over-the-counter basis and partially through electronic interdealer brokers (IDBs).

The current Canadian IDBs are screen-based voice brokers that allow dealers to trade anonymously with each other. Each participant has a screen where bids, offers, and trade outcomes are posted. Participants post quotes and make trades by communicating with the broker over the telephone. Given the large and unpredictable inventory shocks typically faced by dealers in their trades with customers, interdealer debt markets have developed to facilitate inventory management and risk sharing. Whereas only dealers can post quotes or trade through the IDBs, both customers and dealers have viewing access to an IDB's electronic screens. The introduction of IDBs has significantly reduced the role of bilateral interdealer trading in recent years.

The level of transparency in the IDB market was enhanced on 20 August 2001 with the introduction of CanPX,[13] a data service that consolidates and disseminates to interested

12. More recently, electronic platforms have been introduced in Canada that offer simultaneous multiple-dealer quote inquiries and trading in one case, and peer-to-peer, order-driven trading in another.
13. Zorn (2004) elaborates on recent discussions between regulators, academics, and market participants associated with the issue of transparency and regulation in Canadian fixed-income markets.

subscribers anonymous trade and quote data submitted by Canada's fixed-income IDBs. Based on dealer statistics reported to the Investment Dealers Association (IDA), the Canadian interdealer debt market represented approximately 46 per cent of the total secondary Government of Canada bond market trading volume during 2002, of which IDB trading accounted for 86 per cent (up from 50 per cent in 1991 and 75 per cent in 1997). This is comparable to the U.S. Treasury market, where the interdealer market accounted for 50 per cent of activity in 1997, of which trading on IDBs has been estimated to represent between 90 and 99 per cent (Gravelle 2002).

An important feature of IDB trading is that, although a trade must occur at the last quoted price, once it has been initiated its size is subject to negotiation if both parties are willing. In addition, once other IDB participants become aware through the system that a trade has been initiated at a particular price, they may join in (on either side of the trade) once the trading needs of the original buyer or seller have been met. This is referred to as the "workup" process, and it continues until either total buying or selling interest with respect to that trade has been satisfied.[14] Far from being an uncommon occurrence, it is quite common for a $2 million quote to eventually result in a trade of several times the initial posted size.

3. Theoretical Predictions

In this section, we discuss the predictions of several asymmetric information microstructure models with respect to the behaviour of trading activity, volatility, and liquidity in financial markets around the release of relevant market information. Keep in mind the two different types of news events examined in this paper: the release of macroeconomic news, and the release of the results of a Government of Canada bond auction. Although the type of information released to the public is different, and the sources of asymmetric information may be different, both releases are scheduled for predetermined times and dates, and both releases of news are nearly instantaneous. Furthermore, the method in which information is processed, instantaneously and through order flow or trades, is the same.

Market microstructure models[15] generally assume that there are two classes of traders: uninformed liquidity traders and informed traders. Traders submit orders to a risk-neutral market-maker who aggregates all orders and clears all trades at a single price. Informed traders have private information that allows them to profit in their trades with uninformed liquidity traders and market-makers. To help offset the effects of adverse selection, market-makers reduce liquidity

14. Boni and Leach (2002) provide an excellent description of the "right-of-refusal" limit order expansion protocol.

15. See Admati and Pfleiderer (1988), Easley and O'Hara (1992), and Glosten and Milgrom (1985).

when the probability of trading against an informed trader is high. Uninformed traders, who demand liquidity, are hesitant to trade prior to an anticipated event because they fear being exploited by informed traders.

When the timing of a news release is common knowledge to the market, theory predicts that liquidity will deteriorate before the release. Kim and Verrecchia (1994) present a model in which investors actively gather private information prior to a news release, with the intent of profitably trading on this information. Informed traders in government securities may be better able to process public information, or they may have access to a larger proportion of market order flow. The pre-event information-gathering leads to increased informational asymmetry between the informed and uninformed. Trading volumes may fall prior to the news event because uninformed traders stay away.

At the news release, price volatility will increase temporarily with the amount of new information impounded into market prices, representing the revision in investors' beliefs. Trading volumes may fall with this uncertainty. As soon as the new information is fully processed by the market, however, volatility should decline, along with the reduced informational asymmetry in the market. Afterwards, there may be a period of increased trading volumes and trade and quote activity as investors rebalance their portfolios. Alternatively, if informed traders trade on their information prior to the release of news, the impact of the public information when it is released will be smaller, thereby reducing volatility. The quickness with which the market returns to normal will indicate how liquid the market is, and how well the market processes new information.

Drudi and Massa (2001) find empirical support for a theoretical model in which informed dealers trade in parallel markets, such as the primary and secondary government securities markets, to take advantage of differences in transparency across the markets. Traders will place sell orders in the interdealer secondary market at a time when they have an informational advantage suggesting higher prices. Concurrently, they will aggressively place bids in the primary market. The strategy generates losses in the more-transparent market (the secondary market), but larger gains in the less-transparent market (the primary market). The model predicts increased liquidity prior to the auction cut-off, as informed traders generate liquidity in the market in an attempt to manipulate uninformed traders. Once the results of the auction are revealed, there is little disagreement about the interpretation of the news, so volatility falls. The unwinding of speculative positions or portfolio rebalancing may be expected to lead to a trade volume surge, but not wider bid/ask spreads.

4. Data

Our sample of trade and quote data covers the period from 4 July 2001 to 10 September 2001, and 25 February 2002 to 27 February 2003.[16] The CanPX data set is relatively complete, in that it receives information from all of the Canadian IDBs.[17] Dealers leave firm quotes with the brokers, along with a minimum size that they are willing to trade. The best quotes across all the participating dealers are posted. Unlike stock exchanges, dealer behaviour is not governed by rules that limit bid/ask spreads or price changes, so prices can adjust endogenously.

The following trade and quote information relating to a particular security is available on the CanPX screen: the price and/or yield of the best bid and offer (if any); the total amount offered and bid at each of the best inside quotes (across all of the IDB screens); the time at which the best bid and offer were last updated; whether a buyer-initiated or seller-initiated trade is currently being conducted; and, when a trade is completed, the trade outcome and the name of the IDB where the trade took place. Our raw data provide a snapshot of the information on the CanPX screen, downloaded each time the screen changes. The data contain a significant amount of repetition and a number of data-entry errors. They were filtered prior to performing our analysis.[18]

In this study, we focus on benchmark Government of Canada bonds in the 2-, 5-, 10-, and 30-year sectors. These securities are the most actively traded and quoted issues on the IDBs. The benchmark for a given sector is the most recently issued security, with a cumulative issue size over a certain threshold. The identity of the benchmark bond in each maturity sector changes periodically, as old securities move out of the maturity sector and new securities are issued to take their places. This paper follows convention in identifying the benchmarks based on the Government of Canada's issuance calendar.

Macroeconomic news announcements and the release of securities auction results occur at scheduled times. All of the macroeconomic news announcements we consider occur at 8:30 a.m., Eastern Standard Time. We use six Canadian news announcements (producer price index (PPI), real gross domestic product, current account, merchandise trade balance, retail sales, and raw

16. Data for the five-and-one-half month period immediately following 11 September 2001 are not available.
17. Over our sample period, the Canadian IDBs included: Freedom International Brokerage Company, Prebon Yamane (Canada) Ltd., Shorcan Brokers Limited, and Tullett Liberty (Canada) Ltd. The CanPX data set does not include information on the Canadian IDB "roll" markets, where dealers trade one security for another on a spread basis.
18. The filtering methodology is discussed in D'Souza, Gaa, and Yang (2003).

materials price index) and nine U.S. economic announcements (non-farm payrolls, CPI, PPI, unemployment, hourly earnings, trade in goods and services, final gross domestic product, housing starts, and U.S. retail sales).[19] There are 199 days with no 8:30 a.m. macroeconomic announcement and 101 days with one 8:30 a.m. macroeconomic release.

Over the period 4 July 2001 to 8 December 2002, the bidding deadline for Government of Canada bond auctions was 12:30 p.m. The results of bond auctions were released at 12:45 p.m. during this period, but starting 9 December 2002, results were announced at 12:40 p.m. Our sample uses 24 auctions, broken down as follows: six 2-year auctions, five 5-year auctions, eight 10-year auctions, and five 30-year auctions.

Our sample consists of just over 14 months of trade and quote data. There are too few 8:30 a.m. macroeconomic news announcements and too few bond auctions during this period to identify statistically significant effects related to the impact of each type of macroeconomic announcement or each auction maturity on secondary market dynamics. Therefore, all macroeconomic news announcements are pooled together and all auctions are pooled across maturities.[20] In this paper, we focus on analyzing how liquidity adjusts when information is revealed to the market, and not the overall price or yield change.

While we analyze trade and price dynamics on days with and without a news release, we also contrast differences in dynamics on days with a large news surprise and days with a small news surprise. It can be argued that dynamics on days that have a small news surprise will reflect anticipated changes in liquidity, whereas the dynamics on days that have a large news surprise will be representative of anticipated and unanticipated liquidity.

In order to study the effects of large and small macroeconomic surprises on liquidity, we must first calculate the surprise component of each macroeconomic news announcement. Let F_{it} denote the median forecast in the Money Market Services (MMS) survey and let A_{it} denote the release value for announcement type i, in period t. The surprise in announcement i, in period t, is $E_{it} = A_{it} - F_{it}$. Since units of measurement differ across types of economic news announcements, it is necessary to divide each surprise by the standard deviation of the type of announcement (calculated using all observations of announcement i). The standardized surprise measure is $S_{it} = E_{it}/\sigma_i$. Taking all standardized surprises together (101 announcements in total), those that are larger than one standard deviation from the mean standardized surprise are

19. The set of news announcements we use is based on the study by F&R.

20. Since benchmarks have been built up and achieve "benchmark" status only near the end of the build-up, most of the bonds whose auctions we focus on are not the same as the bonds whose price and trade dynamics we analyze in the secondary market.

categorized as large macroeconomic surprise announcements (26 of 101),[21] and the rest are categorized as small macroeconomic surprise announcements (75 of 101).

5. Liquidity Measures

In general, a liquid market is one where market participants can rapidly execute large transactions with only a small impact on prices. Although an exact measure of market liquidity is not available, it is typically characterized by trading volumes or, if transaction level data are available, the bid/ask spread. We use a number of statistics that may together provide a meaningful measure of liquidity. In examining the conditions associated with our two types of events, we consider a number of variables: volatility, trading volume, trade frequency, quote frequency, bid/ask spreads, quote size, order expansion, and price-impact coefficients. D'Souza, Gaa, and Yang (2003) find that bid/ask spreads and price-impact coefficients are the most appropriate indicators of liquidity.

Trading volume, or the total value of securities traded per unit of time, is an intuitive and widely cited measure of market liquidity, stemming from the fact that active markets tend to be more liquid. The popularity of the measure may reflect its simplicity and availability. Theoretical studies have established a positive link between trading volume and liquidity, suggesting that higher trading volume is associated with greater market liquidity. However, one drawback of trading volume as a liquidity indicator is that it is also associated with price volatility (Andersen 1996, Karpoff 1987), which is thought to be negatively related to market liquidity. Trading volume has shown mixed empirical results as a proxy for market liquidity.

Closely related to trading volume, trade frequency—or the number of trades observed per unit of time—is another indirect measure of liquidity. Like trading volume, trade frequency may also be associated with volatility and lower liquidity. The relationship between trading volume and price changes is muddled by the endogenous nature of trade size, because trade size depends on a negotiation that depends on the liquidity of the market. When the market is liquid, a dealer may well be able to execute a large trade at the best quoted price, either because the quoted quantity is large or because the dealer can negotiate a large quantity. Thus, trading frequency may be more relevant than trade volume. It does not include any effects from changes in trade size. As a further measure of market activity, we count the number of non-repeated quotes in each time interval. This measure is referred to as quote frequency.

21. The mean standardized surprise = -0.0319, and the standard deviation of standardized surprises = 0.6766.

The bid/ask spread, or the difference between the best bid and offer prices, is a commonly used measure of market liquidity. It measures directly the costs of executing a small trade, and a market with very low transaction costs is characterized as liquid. The measure can be calculated quickly from data that are widely available on a real-time basis. One limitation of the bid/ask spread, however, is that a spread is good for only a specific set of bid and ask quote sizes.

Quote size is an appealing proxy for market depth. Often, however, only the inside quotes at the best bid and ask prices are visible, leaving the rest of the order book effectively invisible to observers. The quantity that can be traded at the bid and offer prices helps account for the depth of the market and complements the bid/ask spread as a measure of market liquidity. Unfortunately, CanPX captures and stores data that relate only to the inside quotes. Furthermore, observed quote size underestimates true market depth, where participants may actually be willing to transact more than they explicitly quote. For instance, trades often go through trade expansion, in which a broker mediates an increase in trade size beyond the amount quoted.

The brokered interdealer government securities markets feature a practice known as trade expansion, or a "workup."[22] When a quote is "hit" or "lifted," the workup protocol allows further negotiations over size to take place. At each stage of the negotiation, each participant retains right-of-refusal with respect to further size expansion, and trade size will continue to grow until underlying demand on one side or the other has been met. Furthermore, once the trade has been initiated, the associated quote begins to flash on the broker's screen, alerting other participants on the system that a trade is in progress. Once the initial buyer's and/or seller's demand has been satisfied, other dealers are allowed to trade at that price.

One explanation for the use of a workup is that it allows participants to minimize information leakage with respect to their true trading desires. Instead of posting a large quote (which could move the market price against them), the dealer posts a small initial quote, subsequently revealing their true demand only incrementally, and only to the prospective counterparty. As Boni and Leach (2002) suggest, we might expect participants to make relatively greater use of trade size expansion under relatively illiquid (or otherwise adverse) market conditions, when concerns regarding information leakage and stale quotes may be at their highest. We propose two liquidity measures based on participants' use of the order expansion protocol: (i) the proportion of total trades that have undergone size expansion, and (ii) the proportion of total trading volume from trades that have undergone size expansion.

22. Boni and Leach (2002) provide an excellent description of the right-of-refusal limit order expansion protocol in the interdealer U.S. Treasury market.

Kyle (1985) develops a model to address the strategic aspects of informed trading in a market microstructure model. The model is able to characterize how an informed trader would choose to transact in order to maximize the value of private information. The price-impact coefficient in the model reflects how much the market adjusts prices to the information content of trades or order flow. Kyle's price-impact coefficient can be used to characterize liquidity in financial markets because it is generally believed that liquid markets are those which accommodate trades with the least impact on prices. The price-impact measure is defined as the slope of the line that relates the price change to trade size and is typically estimated via a regression. We estimate price impact by regressing log changes in prices, computed using bid/ask midpoints, on one of two measures of order flow (OF) over a 5-minute interval:

$$\log(P_t) - \log(P_{t-1}) = \beta_0 + \beta_1 \times OF_t + \varepsilon_t. \qquad (1)$$

Order flow is measured by the volume of buyer-initiated trades minus the volume of seller-initiated trades, and the number of buyer-initiated trades minus the number of seller-initiated trades over the 5-minute interval. A drawback of this measure is that the data required for estimation are often difficult to obtain.

6. Statistical Methodology

The event study that we conduct attempts to characterize price and trade dynamics in the Government of Canada secondary market on days with and without news releases. We examine intraday price and trade dynamics in the secondary market for Government of Canada securities, focusing, in particular, on the times just before and just after the release of news. We contrast "normal" trade and price dynamics, determined on non-event days, with those on event days. The null hypothesis tested in this paper is that trade and price dynamics are similar on event and non-event days. To control for intraday seasonal patterns, we use an event study approach.

We determine statistically significant differences in liquidity measures on announcement and non-announcement days, and on auction and non-auction days, using a number of parametric and non-parametric tests.[23] The advantage of using a non-parametric test is that an assumption about the distribution of each liquidity measure does not have to be made. Table 1 illustrates that the assumption of normality is violated for all liquidity measures. Brown-Forsythe-modified Levene F-statistics are calculated to compare the variance in prices on event and non-event days. Under the null hypothesis of homoscedasticity, or equal variances across samples, the statistic is

23. The appendix provides a detailed explanation of each test statistic.

distributed as $F(1, N-2)$. The Brown-Forsythe-modified Levene test is robust against departures from normality, and does not require equal sample sizes. The Kruskal-Wallis test is used to test whether there is a statistically significant difference between the means of each liquidity measure on event and non-event days. The test statistic is distributed $\chi^2(J-1)$ under the null hypothesis of equal medians. One of the advantages of non-parametric procedures is that they are not severely affected by changes in a small proportion of the data (such as the inclusion of an extreme event). Both parametric and non-parametric tests are documented. After we estimate the price impacts of signed trades and volumes using equation (1), we calculate F-statistics to test for differences in the slope coefficients in the two samples.

7. Results

7.1 Volatility

Differences in the average level of volatility on event and non-event days are plotted cumulatively throughout the day for each benchmark bond in Figures 1 to 8. Cumulative absolute average returns (CAARs) are calculated by subtracting the absolute return (a measure of volatility) in each 5-minute interval on non-event days from the absolute return on event days. A large positive slope in the graph reflects a large relative increase in volatility on event days. Interestingly, Figures 1 to 8 show a persistent reaction, lasting anywhere from two to four hours, subsequent to both an 8:30 a.m. macroeconomic news release and the release of the results of a Government of Canada bond auction. Theory suggests that price volatility will increase as information is impounded into market prices, and it will remain high until a consensus view is reached. It is important to note that these figures indicate nothing about the statistical significance of the relative levels of volatility on event and non-event days.

Table 3 documents the average level of volatility for the 2-year benchmark bond in a series of 5-minute intervals before and after each news release. Time intervals are used to best measure intraday adjustments in the volatility of prices. The first four panels in Tables 3 to 13 relate to macroeconomic news announcements. Each panel compares two groups of days: Panel 1 compares all days with an 8:30 a.m. news announcement and all days without an 8:30 a.m. news announcement; Panel 2 compares all days with an 8:30 a.m. large surprise announcement and all days without an 8:30 a.m. news announcement; Panel 3 compares all days with an 8:30 a.m. small surprise announcement and all days without an 8:30 a.m. news announcement; Panel 4 compares all days with an 8:30 a.m. large surprise announcement and all days with an 8:30 a.m. small surprise announcement. Changes in volatility on small surprise announcement days are, to some extent, expected by the market. Unexpected changes in volatility, if any, would occur on days with

a large surprise macroeconomic announcement. At the bottom of Tables 3 to 13 in Panel 5, average levels of volatility are documented on those days with and without a Government of Canada bond auction. The same format is used in Tables 3 to 13 to analyze the behaviour of each liquidity measure for the 2-year benchmark bond.[24] In these tables, we document whether any statistical difference exists between the liquidity measures on event and non-event days. Table 2 summarizes results for the 5-, 10-, and 30-year benchmark bonds. There are many similarities across bond maturities.

Volatility is significantly higher on days of macroeconomic news announcements than non-announcement days for 20 minutes following the release of news. This amount of time reflects how long it takes for traders in the market, as a group, to adjust their beliefs and form a consensus view. There is no statistical difference in volatility on large and small macroeconomic surprise days after the release of news but, interestingly, volatility is higher on large surprise announcement days in the half-hour that precedes the release.

Dynamics are substantially different around an auction. Volatility is relatively higher just prior to the release of an auction's results (or, alternatively, just after the auction cut-off time) and lower in the five minutes that follow the release. After that point, there is no significant evidence of relatively higher volatility on auction days, which suggests that market participants are able to process the publicly released information quickly. The result may also be reflective of dealers trading on their informational advantage prior to release of the auction results. Recall that informed traders may possess superior information prior to a news event, but that their advantage is partially or completely ameliorated by the news event.

7.2 Liquidity measures

Average intraday liquidity measures on days with and without macroeconomic news, and on days with and without government securities auctions, are graphed in Figures 9 to 20. These figures indicate persistently higher trade and quote activity following the release of news. Tables 4, 5, and 6 indicate that trading volumes, and trade and quote frequencies, exhibit similar patterns. Each variable is statistically higher on announcement days during the 5 minutes before, and the 25 minutes following, the release of macroeconomic news. The latter reflects the processing of new information by market participants. Again, dynamics are quite different on auction days. Trading volumes, and trade and quote frequencies, are all significantly higher on auction days in the 15 minutes prior to the auction cut-off. Informed traders may be attempting to exploit their

24. Similar tables for the 5-, 10-, and 30-year benchmarks are available from the authors.

informational advantage during this time. All activity variables are significantly higher on auction days in the 20 minutes following the release of the results of an auction. Since volatility is not significantly different during this period, the result points to the unwinding of speculative positions, or portfolio rebalancing, instead of trading activity based on differences in dealer views.

Table 7 provides evidence that bid quote sizes are significantly lower on announcement days for the five minutes that follow the release of macroeconomic news. Table 8 points to ask quote sizes that are significantly lower on announcement days for the 10 minutes before the release of macroeconomic news, and for the 5 minutes before the auction cut-off. Dealers evidently reduce the trade size of their quotes in response to inventory risks or the potential for sharp price changes.

It is necessary to focus on a longer time interval than five minutes to analyze liquidity measures related to the workup process and the price impact of trades. A 30-minute interval is used, since more than a few trades are necessary to obtain estimates of these measures. Tables 9 and 10 indicate that there is little difference in the amount of trades, or the proportion of trade volume, worked up on event and non-event days. This is consistent with the results of D'Souza, Gaa, and Yang (2003), who find that workup measures are not an accurate measure of liquidity in the market.

In Figure 10, lower bid/ask spreads are shown to persist for more than three hours following the release of macroeconomic news, whereas, in Figure 16, lower-than-normal bid/ask spreads are observed prior to the cut-off time of an auction. Spreads widen after the auction cut-off time, and do not return to normal levels for up to two hours. Table 11 indicates that bid/ask spreads are statistically higher on announcement days for the five minutes before and after the release of macroeconomic news. The wider bid/ask spreads reflect dealer reluctance to make markets at a time when prices may adjust sharply. There is no statistical difference in bid/ask spreads on large and small macroeconomic surprise days prior to or following the release of news. Spreads are lower on auction days in the 5 to 10 minutes prior to an auction cut-off. Liquidity will increase if dealers attempt to exploit their informational advantage prior to the auction cut-off. Bid/ask spreads are significantly higher during the 5 minutes before, and the 10 minutes after, the release of the auction results. Spreads widen dramatically, driven by inventory-control considerations and concerns about the presence of informed traders.

Tables 12 and 13 indicate that the price-impact coefficients of net trades and net trading volumes have nearly identical characteristics. Price-impact coefficients are significantly higher on announcement days in the second 30-minute interval following the release of macroeconomic news. Order flow has a significant impact on the prices of all bonds after a macroeconomic release

or an auction, which suggests that new information is being processed in the market via trading. Green (2004) also finds a significant increase in the informational role of trading following economic announcements, suggesting that the release of public information increases the level of information asymmetry in the government bond market. In the 60 to 90 minutes after the release of macroeconomic news, price-impact coefficients are significantly lower on announcement days, which suggests that, once information is processed, uninformative trading occurs in the market as traders rebalance their portfolios in light of the newly discovered prices. The price impact of trades is higher on small vs. large surprise announcement days in the 30 to 60 minutes following the release of news.

Price-impact coefficients are significantly higher on auction days in the 30 minutes before and after the cut-off of an auction. Reduced liquidity arises because of the probability of trading against an informed trader. The auction not only generates information, but also provides the most informed dealers a way to operate without revealing their information to other market participants. This implies that adverse selection should be high, and liquidity accordingly low, after a news event.

7.3 Summary

In the case of macroeconomic news announcements, a two-stage adjustment process to public information is observed in the Government of Canada securities market. This finding is consistent with asymmetric information interpretations of market liquidity and U.S. empirical evidence. In the first stage, bid/ask spreads widen in the 5-minute interval before and after an announcement. In an extended second stage, price volatility, trading volumes, and trade and quote activity increase to higher-than-normal levels following the 8:30 a.m. macroeconomic news release, with statistically and economically significant effects persisting in some cases up to 25 minutes following the event as dealers begin to take positions based on their differential private views. As soon as the new information is impounded into prices, volatility declines. A significant fall in price-impact coefficients denotes a possible third stage. After enough time has elapsed for the market to process the news, liquidity levels surge. Interestingly, we find no important differences in trade and price dynamics between large and small surprise announcement days.

In terms of the price and trade dynamics that surround an auction event, a different three-stage adjustment occurs. The first stage begins in the run-up to the auction cut-off. In this period, trading volumes and trade and quote activity increase, while bid/ask spreads narrow, consistent with theory that suggests that informed traders attempt to exploit their order-flow information by trading aggressively in the market. Traders may also be attempting to manipulate prices in the

market, as suggested by Drudi and Massa (2001), and, in doing so, they increase liquidity, unlike macroeconomic news, where any private information related to superior forecasts is probably already incorporated into prices before the day of the event. Trades just prior to the auction cut-off reflect the arrival of bids from customers. Traders protect themselves from informed trading by increasing their spreads. Significantly higher price-impact coefficients reflect the fact that uninformed traders realize that trades in the market are probably initiated by informed dealers. In the second stage, just prior to, and after, the release of the auction results, liquidity falls. Judging by the increase in spreads, dealers are reluctant to make markets when there is the potential for sharp price changes. The information revealed in the release of the auction results is processed rapidly by the market, so that, in the third stage, trade and quote activity increase without a corresponding increase in volatility as traders rebalance their portfolios.

8. Conclusion

While two distinct patterns in price and trade dynamics are documented around the two information events examined in this paper, they are consistent with theoretical predictions and U.S. empirical evidence. In particular, we find that liquidity varies with the amount of asymmetric information in the market, and that order flow plays a central role in the processing of information. Further, Canadian government securities markets react to macroeconomic news announcements in a manner similar to the highly liquid U.S. Treasury market. In general, we find that news is processed in an efficient and timely manner, which suggests that the quality of the government securities markets in Canada may be adequate.

Characterizing liquidity dynamics in government securities markets around periods of market uncertainty is important from a financial system perspective, where the promotion of efficient and resilient financial markets is an objective of policy-makers. The ability of markets to process news quickly and efficiently will indicate how these markets would behave when an unexpected shock arises. The failure of financial institutions to take into account changes in market liquidity during stressful times, and the two-way causality between financial market shocks and sharp reductions in market liquidity, was identified by the Committee on the Global Financial System,[25] of the G-10 central banks, as a concern regarding financial markets. The results of this paper may contribute to a deeper understanding of financial markets, so that policy-makers can act to ensure robust and efficient financial systems.

25. Web site: http://www.bis.org/publ/cgfs12.htm.

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Table 1: Normality Test Statistics

	Test statistic
Price returns	430.80
Trading volume	533.04
Bid/ask spread	87.98
Trade frequency	157.48
Quote frequency	125.10
Ask quote size	2236.10
Bid quote size	768.89
χ (2)=5.99 at the 95 per cent level, χ (2)=9.2 at the 99 per cent level	

Table 2: Summary of Results

		Less than 30 minutes before event	Less than 10 minutes after event	Up to 30 minutes after event	Up to 60 minutes after event	Up to 90 minutes after event
8:30 a.m. macroeconomic news announcement						
Table 3	Volatility	2y, 5y, 10y, 30y (large > small)	2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (higher)		
Table 4	Trading volume		2y, 10y (higher)	2y, 10y (higher)		
Table 5	Trade frequency		2y, 10y (higher)	2y, 10y (higher)		
Table 6	Quote frequency		2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (higher)		
Table 7	Bid quote size		2y, 10y (lower)			
Table 8	Ask quote size	2y, 10y (lower)				
Tables 9 & 10	Order expansion					
Table 11	Bid/ask spread	2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (higher)			
Tables 12 & 13	Price impact		2y, 5y, 10y, 30y (small > large)		2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (lower)
12:40 or 12:45 p.m. auction release						
Table 3	Volatility	2y, 5y, 10y, 30y (higher)	2y, 30y (lower)			
Table 4	Trading volume	2y, 5y, 10y, 30y (higher)		2y, 5y, 10y, 30y (higher)		
Table 5	Trade frequency	2y, 5y, 10y, 30y (higher)		2y, 5y, 10y, 30y (higher)		
Table 6	Quote frequency	2y, 5y, 10y, 30y (higher)		2y, 5y, 10y, 30y (higher)		
Table 7	Bid quote size					
Table 8	Ask quote size	2y (lower)				
Tables 9 & 10	Order expansion					
Table 11	Bid/ask spread	2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (higher)			
Tables 12 & 13	Price impact	2y, 5y, 10y, 30y (higher)	2y, 5y, 10y, 30y (higher)			

2y, 5y, 10y, 30y represent significance of test statistics at greater than the 90 per cent level.

Table 3: 2-Year Benchmark, Volatility

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	0.007	0.007	0.006	0.009	0.008	0.011	0.025	0.022	0.016	0.013	0.011	0.011
Non-announcement days, mean	0.007	0.008	0.008	0.007	0.012	0.009	0.020	0.010	0.008	0.009	0.011	0.008
Ratio of means	0.973	0.900	0.707	1.179	0.715	1.192	1.225	2.215	1.855	1.330	0.987	1.413
Modified Levene F-statistic	0.100	0.300	1.053	0.051	2.674	0.797	2.546	21.02	18.21	3.513	0.995	2.361
Modified Levene, *p*-value	0.752	0.585	0.306	0.822	0.103	0.374	0.113	0.000	0.000	0.062	0.320	0.126
Panel 2: Large surprise announcements												
Announcement days, mean	0.011	0.009	0.005	0.013	0.013	0.017	0.013	0.017	0.015	0.011	0.009	0.013
Non-announcement days, mean	0.007	0.008	0.008	0.007	0.012	0.009	0.020	0.010	0.008	0.009	0.011	0.008
Ratio of means	1.450	1.248	0.590	1.810	1.091	1.915	0.624	1.708	1.837	1.125	0.859	1.701
Modified Levene F-statistic	7.117	1.097	0.831	1.287	0.014	2.277	0.029	14.80	8.062	0.000	0.010	3.091
Modified Levene, *p*-value	0.008	0.297	0.363	0.258	0.905	0.134	0.866	0.000	0.005	0.994	0.921	0.081
Panel 3: Small surprise announcements												
Announcement days, mean	0.005	0.006	0.006	0.006	0.006	0.008	0.029	0.023	0.015	0.013	0.011	0.010
Non-announcement days, mean	0.007	0.008	0.008	0.007	0.012	0.009	0.020	0.010	0.008	0.009	0.011	0.008
Ratio of means	0.721	0.752	0.751	0.839	0.518	0.935	1.410	2.317	1.840	1.395	1.033	1.303
Modified Levene F-statistic	1.339	1.694	0.497	1.172	4.628	0.001	3.291	15.27	16.78	5.149	1.568	1.213
Modified Levene, *p*-value	0.249	0.195	0.482	0.280	0.033	0.975	0.072	0.000	0.000	0.024	0.212	0.272
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	0.011	0.009	0.005	0.013	0.013	0.017	0.013	0.017	0.015	0.011	0.009	0.013
Small announcement days, mean	0.005	0.006	0.006	0.006	0.006	0.008	0.029	0.023	0.015	0.013	0.011	0.010
Ratio of means	2.012	1.660	0.786	2.158	2.104	2.049	0.443	0.737	0.999	0.806	0.831	1.305
Modified Levene F-statistic	14.63	3.605	0.363	2.336	3.436	1.293	0.749	0.004	0.009	1.336	0.941	0.626
Modified Levene, *p*-value	0.000	0.061	0.548	0.130	0.068	0.270	0.398	0.949	0.925	0.251	0.335	0.431
Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	0.006	0.006	0.003	0.013	0.009	0.002	0.013	0.010	0.010	0.009	0.005	0.011
Non-auction days, mean	0.009	0.008	0.008	0.006	0.009	0.008	0.008	0.009	0.008	0.009	0.008	0.007
Ratio of means	0.661	0.686	0.419	2.003	1.001	0.251	1.651	1.145	1.355	1.019	0.606	1.675
Modified Levene F-statistic	0.049	0.636	2.092	3.016	1.250	2.908	2.051	0.359	3.636	0.315	0.695	3.408
Modified Levene, *p*-value	0.825	0.426	0.149	0.084	0.265	0.089	0.153	0.550	0.058	0.575	0.405	0.066

Volatility: Standard deviation in the midpoint of the bid/ask spread over the interval

Table 4: 2-Year Benchmark, Trading Volume

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	2.232	6.020	2.071	4.081	6.848	6.192	5.545	15.68	8.712	8.414	10.62	5.657
Non-announcement days, mean	3.352	3.497	4.691	2.509	4.452	5.042	4.139	7.006	5.621	6.939	6.433	6.552
Ratio of means	0.666	1.722	0.441	1.626	1.538	1.228	1.340	2.238	1.550	1.213	1.652	0.863
t-statistic, *p*-value	0.396	0.241	0.143	0.268	0.124	0.529	0.362	0.004	0.134	0.573	0.083	0.711
Kruskal-Wallis test, *p*-value	0.729	0.979	0.452	0.975	0.498	0.029	0.061	0.000	0.004	0.032	0.025	0.304
Panel 2: Large surprise announcements												
Announcement days, mean	5.308	12.07	1.462	0.962	3.269	5.231	7.885	22.44	7.615	6.577	6.385	5.192
Non-announcement days, mean	3.352	3.497	4.691	2.509	4.452	5.042	4.139	7.006	5.621	6.939	6.433	6.552
Ratio of means	1.584	3.454	0.312	0.383	0.734	1.037	1.905	3.203	1.355	0.948	0.992	0.793
t-statistic, *p*-value	0.436	0.023	0.336	0.342	0.590	0.950	0.165	0.002	0.524	0.935	0.988	0.757
Kruskal-Wallis test, *p*-value	0.436	0.691	0.956	0.312	0.355	0.320	0.398	0.000	0.007	0.591	0.734	0.197
Panel 3: Small surprise announcements												
Announcement days, mean	1.137	3.863	2.288	5.192	8.123	6.534	4.712	13.27	9.103	9.068	12.13	5.822
Non-announcement days, mean	3.352	3.497	4.691	2.509	4.452	5.042	4.139	7.006	5.621	6.939	6.433	6.552
Ratio of means	0.339	1.105	0.488	2.069	1.825	1.296	1.138	1.895	1.620	1.307	1.887	0.889
t-statistic, *p*-value	0.102	0.838	0.248	0.101	0.035	0.467	0.720	0.038	0.141	0.477	0.038	0.792
Kruskal-Wallis test, *p*-value	0.387	0.854	0.338	0.630	0.195	0.029	0.063	0.000	0.031	0.018	0.010	0.559
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	5.308	12.07	1.462	0.962	3.269	5.231	7.885	22.44	7.615	6.577	6.385	5.192
Small announcement days, mean	1.137	3.863	2.288	5.192	8.123	6.534	4.712	13.27	9.103	9.068	12.13	5.822
Ratio of means	4.668	3.126	0.639	0.185	0.402	0.801	1.673	1.691	0.837	0.725	0.526	0.892
t-statistic, *p*-value	0.036	0.113	0.590	0.214	0.154	0.680	0.274	0.148	0.710	0.544	0.279	0.833
Kruskal-Wallis test, *p*-value	0.183	0.622	0.512	0.233	0.128	0.659	0.783	0.110	0.335	0.404	0.223	0.428
Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	11.08	6.458	1.417	3.208	0.417	1.292	2.833	6.792	1.750	5.250	1.708	6.000
Non-auction days, mean	2.242	1.863	2.657	3.303	1.967	2.624	3.539	2.834	3.328	2.996	3.347	2.542
Ratio of means	4.943	3.466	0.533	0.971	0.212	0.492	0.801	2.397	0.526	1.752	0.510	2.360
t-statistic, *p*-value	0.000	0.003	0.517	0.974	0.195	0.486	0.798	0.072	0.632	0.454	0.449	0.146
Kruskal-Wallis test, *p*-value	0.011	0.001	0.721	0.317	0.847	0.495	0.817	0.010	0.575	0.032	0.785	0.231

Trading volume, or the total value of securities traded per unit of time

Table 5: 2-Year Benchmark, Trade Frequency

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	0.232	0.222	0.253	0.232	0.455	0.566	0.626	1.152	0.808	0.818	0.788	0.475
Non-announcement days, mean	0.261	0.279	0.291	0.261	0.442	0.418	0.388	0.448	0.430	0.473	0.539	0.382
Ratio of means	0.891	0.797	0.868	0.891	1.027	1.353	1.615	2.568	1.878	1.731	1.461	1.243
t-statistic, *p*-value	0.687	0.433	0.623	0.694	0.906	0.197	0.022	0.000	0.001	0.006	0.033	0.403
Kruskal-Wallis test, *p*-value	0.833	0.827	0.489	0.884	0.673	0.030	0.059	0.000	0.002	0.020	0.013	0.311
Panel 2: Large surprise announcements												
Announcement days, mean	0.385	0.269	0.269	0.231	0.308	0.500	0.538	1.192	0.923	0.615	0.615	0.462
Non-announcement days, mean	0.261	0.279	0.291	0.261	0.442	0.418	0.388	0.448	0.430	0.473	0.539	0.382
Ratio of means	1.476	0.966	0.925	0.886	0.695	1.196	1.388	2.659	2.145	1.302	1.141	1.209
t-statistic, *p*-value	0.321	0.941	0.865	0.814	0.436	0.669	0.327	0.000	0.004	0.418	0.690	0.626
Kruskal-Wallis test, *p*-value	0.374	0.823	0.941	0.403	0.395	0.315	0.519	0.000	0.003	0.553	0.757	0.184
Panel 3: Small surprise announcements												
Announcement days, mean	0.178	0.205	0.247	0.233	0.507	0.589	0.658	1.137	0.767	0.890	0.849	0.479
Non-announcement days, mean	0.261	0.279	0.291	0.261	0.442	0.418	0.388	0.448	0.430	0.473	0.539	0.382
Ratio of means	0.683	0.737	0.848	0.894	1.146	1.409	1.695	2.535	1.783	1.884	1.575	1.256
t-statistic, *p*-value	0.270	0.362	0.613	0.719	0.577	0.183	0.017	0.000	0.007	0.003	0.015	0.439
Kruskal-Wallis test, *p*-value	0.449	0.696	0.371	0.798	0.342	0.030	0.047	0.000	0.023	0.011	0.004	0.584
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	0.385	0.269	0.269	0.231	0.308	0.500	0.538	1.192	0.923	0.615	0.615	0.462
Small announcement days, mean	0.178	0.205	0.247	0.233	0.507	0.589	0.658	1.137	0.767	0.890	0.849	0.479
Ratio of means	2.160	1.310	1.092	0.991	0.607	0.849	0.819	1.049	1.203	0.691	0.725	0.963
t-statistic, *p*-value	0.077	0.550	0.872	0.986	0.253	0.648	0.599	0.871	0.525	0.324	0.289	0.938
Kruskal-Wallis test, *p*-value	0.186	0.640	0.507	0.332	0.188	0.703	0.547	0.381	0.277	0.351	0.147	0.392

Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	0.500	0.583	0.167	0.333	0.208	0.167	0.292	0.583	0.208	0.542	0.208	0.458
Non-auction days, mean	0.244	0.218	0.255	0.251	0.262	0.266	0.284	0.221	0.232	0.210	0.292	0.236
Ratio of means	2.053	2.679	0.655	1.328	0.795	0.627	1.027	2.635	0.896	2.575	0.715	1.941
t-statistic, *p*-value	0.061	0.001	0.502	0.576	0.661	0.392	0.961	0.004	0.852	0.007	0.520	0.074
Kruskal-Wallis test, *p*-value	0.020	0.001	0.740	0.268	0.996	0.526	0.741	0.009	0.600	0.024	0.735	0.140

Trade frequency: the number of trades observed per unit of time

Table 6: 2-Year Benchmark, Quote Frequency

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	3.707	3.970	4.495	4.010	5.303	6.707	12.12	12.74	11.40	9.131	9.414	7.707
Non-announcement days, mean	4.042	4.139	4.842	4.648	6.018	6.267	8.279	7.497	7.000	6.073	6.812	6.479
Ratio of means	0.917	0.959	0.928	0.863	0.881	1.070	1.464	1.700	1.629	1.504	1.382	1.190
t-statistic, *p*-value	0.556	0.793	0.560	0.257	0.334	0.592	0.001	0.000	0.000	0.001	0.004	0.120
Kruskal-Wallis test, *p*-value	0.584	0.213	0.713	0.190	0.888	0.431	0.001	0.000	0.000	0.004	0.003	0.193
Panel 2: Large surprise announcements												
Announcement days, mean	4.808	4.346	4.692	4.000	5.500	6.846	9.654	13.42	9.846	8.000	7.769	7.462
Non-announcement days, mean	4.042	4.139	4.842	4.648	6.018	6.267	8.279	7.497	7.000	6.073	6.812	6.479
Ratio of means	1.189	1.050	0.969	0.860	0.914	1.092	1.166	1.790	1.407	1.317	1.141	1.152
t-statistic, *p*-value	0.458	0.860	0.884	0.488	0.695	0.661	0.417	0.000	0.032	0.120	0.487	0.412
Kruskal-Wallis test, *p*-value	0.228	0.398	0.664	0.662	0.971	0.274	0.457	0.004	0.004	0.374	0.672	0.445
Panel 3: Small surprise announcements												
Announcement days, mean	3.315	3.836	4.425	4.014	5.233	6.658	13.00	12.50	11.95	9.534	10.00	7.795
Non-announcement days, mean	4.042	4.139	4.842	4.648	6.018	6.267	8.279	7.497	7.000	6.073	6.812	6.479
Ratio of means	0.820	0.927	0.914	0.863	0.870	1.062	1.570	1.668	1.708	1.570	1.468	1.203
t-statistic, *p*-value	0.247	0.675	0.522	0.316	0.343	0.673	0.000	0.000	0.000	0.001	0.001	0.132
Kruskal-Wallis test, *p*-value	0.979	0.282	0.827	0.170	0.879	0.703	0.000	0.000	0.000	0.002	0.001	0.235
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	4.808	4.346	4.692	4.000	5.500	6.846	9.654	13.42	9.846	8.000	7.769	7.462
Small announcement days, mean	3.315	3.836	4.425	4.014	5.233	6.658	13.00	12.50	11.95	9.534	10.00	7.795
Ratio of means	1.450	1.133	1.060	0.997	1.051	1.028	0.743	1.073	0.823	0.839	0.777	0.957
t-statistic, *p*-value	0.068	0.550	0.791	0.989	0.804	0.900	0.141	0.679	0.279	0.498	0.219	0.838
Kruskal-Wallis test, *p*-value	0.197	0.860	0.801	0.560	0.971	0.432	0.096	0.845	0.449	0.349	0.084	0.997

Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	5.500	4.375	2.708	2.667	3.667	2.042	5.292	6.667	6.708	6.375	5.625	4.917
Non-auction days, mean	4.041	3.697	3.745	3.849	4.177	3.775	4.240	4.103	3.911	3.989	4.362	4.007
Ratio of means	1.361	1.183	0.723	0.693	0.878	0.541	1.248	1.625	1.715	1.598	1.290	1.227
t-statistic, *p*-value	0.136	0.446	0.220	0.167	0.602	0.039	0.322	0.022	0.009	0.014	0.245	0.399
Kruskal-Wallis test, *p*-value	0.037	0.845	0.370	0.312	0.915	0.014	0.439	0.008	0.001	0.005	0.329	0.278

Quote frequency: the number of quotes observed per unit of time

Table 7: 2-Year Benchmark, Bid Size

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	3.241	3.604	3.567	4.023	3.193	2.364	3.386	3.753	3.449	4.711	3.489	3.420
Non-announcement days, mean	3.557	3.986	3.643	3.633	3.924	3.351	3.858	4.438	4.503	4.688	4.630	4.079
Ratio of means	0.911	0.904	0.979	1.107	0.814	0.705	0.878	0.846	0.766	1.005	0.754	0.838
t-statistic, *p*-value	0.488	0.576	0.905	0.482	0.226	0.189	0.546	0.559	0.196	0.987	0.212	0.218
Kruskal-Wallis test, *p*-value	0.969	0.742	0.084	0.007	0.524	0.163	0.054	0.454	0.137	0.114	0.128	0.075
Panel 2: Large surprise announcements												
Announcement days, mean	2.818	2.708	3.250	3.500	3.217	3.000	2.591	3.917	3.167	3.125	3.087	2.619
Non-announcement days, mean	3.557	3.986	3.643	3.633	3.924	3.351	3.858	4.438	4.503	4.688	4.630	4.079
Ratio of means	0.792	0.679	0.892	0.963	0.820	0.895	0.672	0.883	0.703	0.667	0.667	0.642
t-statistic, *p*-value	0.349	0.278	0.717	0.878	0.531	0.807	0.286	0.797	0.387	0.438	0.365	0.126
Kruskal-Wallis test, *p*-value	0.467	0.483	0.048	0.042	0.425	0.585	0.087	0.709	0.486	0.381	0.566	0.044
Panel 3: Small surprise announcements												
Announcement days, mean	3.385	3.925	3.682	4.219	3.183	2.125	3.672	3.689	3.537	5.288	3.627	3.672
Non-announcement days, mean	3.557	3.986	3.643	3.633	3.924	3.351	3.858	4.438	4.503	4.688	4.630	4.079
Ratio of means	0.951	0.985	1.011	1.161	0.811	0.634	0.952	0.831	0.785	1.128	0.783	0.900
t-statistic, *p*-value	0.740	0.939	0.959	0.364	0.295	0.163	0.838	0.582	0.299	0.718	0.342	0.503
Kruskal-Wallis test, *p*-value	0.671	0.443	0.276	0.023	0.731	0.043	0.159	0.473	0.152	0.144	0.119	0.261
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	2.818	2.708	3.250	3.500	3.217	3.000	2.591	3.917	3.167	3.125	3.087	2.619
Small announcement days, mean	3.385	3.925	3.682	4.219	3.183	2.125	3.672	3.689	3.537	5.288	3.627	3.672
Ratio of means	0.833	0.690	0.883	0.830	1.011	1.412	0.706	1.062	0.895	0.591	0.851	0.713
t-statistic, *p*-value	0.407	0.187	0.635	0.451	0.926	0.027	0.464	0.880	0.707	0.443	0.543	0.196
Kruskal-Wallis test, *p*-value	0.360	0.234	0.271	0.812	0.611	0.021	0.427	0.945	0.928	0.908	0.577	0.241

Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	3.826	2.800	2.611	2.444	3.632	3.812	3.850	5.696	7.000	2.842	3.750	19.28
Non-auction days, mean	3.519	3.729	4.328	3.449	3.912	3.711	4.022	4.006	4.477	4.716	5.054	4.193
Ratio of means	1.087	0.751	0.603	0.709	0.928	1.027	0.957	1.422	1.563	0.603	0.742	4.600
t-statistic, *p*-value	0.759	0.475	0.416	0.290	0.831	0.938	0.905	0.345	0.251	0.409	0.619	0.000
Kruskal-Wallis test, *p*-value	0.404	0.943	0.432	0.109	0.131	0.137	0.873	0.680	0.895	0.371	0.711	0.524

Bid quote size: average amount posted at the best bid prices in interval

Table 8: 2-Year Benchmark, Ask Size

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	3.241	3.330	3.367	3.205	2.627	2.455	2.843	3.271	4.705	3.422	4.733	4.465
Non-announcement days, mean	3.436	3.496	3.266	3.560	4.034	5.518	5.255	3.861	4.879	4.319	4.519	4.052
Ratio of means	0.943	0.952	1.031	0.900	0.651	0.445	0.541	0.847	0.964	0.792	1.047	1.102
Modified Levene statistic	0.618	0.734	0.841	0.462	0.023	0.445	0.198	0.204	0.870	0.220	0.830	0.710
Modified Levene, *p*-value	0.727	0.687	0.919	0.453	0.006	0.042	0.154	0.246	0.852	0.109	0.283	0.390
Panel 2: Large surprise announcements												
Announcement days, mean	2.864	2.875	4.250	3.875	2.783	2.833	2.955	2.583	3.190	2.792	3.043	2.810
Non-announcement days, mean	3.436	3.496	3.266	3.560	4.034	5.518	5.255	3.861	4.879	4.319	4.519	4.052
Ratio of means	0.833	0.822	1.301	1.088	0.690	0.514	0.562	0.669	0.654	0.646	0.673	0.693
t-statistic, *p*-value	0.364	0.397	0.243	0.727	0.279	0.727	0.527	0.106	0.339	0.219	0.317	0.314
Kruskal-Wallis test, *p*-value	0.558	0.974	0.121	0.433	0.356	0.641	0.358	0.069	0.489	0.240	0.492	0.349
Panel 3: Small surprise announcements												
Announcement days, mean	3.369	3.493	3.045	2.953	2.567	2.312	2.803	3.541	5.179	3.652	5.313	4.984
Non-announcement days, mean	3.436	3.496	3.266	3.560	4.034	5.518	5.255	3.861	4.879	4.319	4.519	4.052
Ratio of means	0.981	0.999	0.933	0.830	0.636	0.419	0.533	0.917	1.061	0.845	1.176	1.230
t-statistic, *p*-value	0.881	0.995	0.667	0.215	0.043	0.495	0.262	0.556	0.806	0.433	0.491	0.463
Kruskal-Wallis test, *p*-value	0.902	0.607	0.462	0.625	0.004	0.031	0.214	0.682	0.904	0.185	0.342	0.570
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	2.864	2.875	4.250	3.875	2.783	2.833	2.955	2.583	3.190	2.792	3.043	2.810
Small announcement days, mean	3.369	3.493	3.045	2.953	2.567	2.312	2.803	3.541	5.179	3.652	5.313	4.984
Ratio of means	0.850	0.823	1.396	1.312	1.084	1.225	1.054	0.730	0.616	0.765	0.573	0.564
t-statistic, *p*-value	0.465	0.497	0.230	0.241	0.509	0.293	0.707	0.113	0.308	0.408	0.224	0.443
Kruskal-Wallis test, *p*-value	0.639	0.708	0.067	0.725	0.216	0.273	0.911	0.163	0.532	0.795	0.974	0.596
Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	3.826	2.500	2.222	2.278	2.474	4.312	4.350	8.348	2.583	2.947	2.750	2.862
Non-auction days, mean	4.182	3.748	3.469	3.577	3.627	4.106	3.991	3.532	3.492	3.494	3.427	4.543
Ratio of means	0.915	0.667	0.641	0.637	0.682	1.050	1.090	2.364	0.740	0.844	0.802	0.630
t-statistic, *p*-value	0.851	0.465	0.217	0.306	0.387	0.907	0.784	0.004	0.264	0.553	0.499	0.401
Kruskal-Wallis test, *p*-value	0.885	0.313	0.035	0.099	0.398	0.803	0.184	0.018	0.506	0.802	0.976	0.217

Ask quote size: average amount posted at the best ask prices in interval

Table 9: 2-Year Benchmark, Workup 1

30 minutes ending at:	8:00	8:30	9:00	9:30	10:00
Panel 1: All announcements					
Announcement days, mean	0.587	0.621	0.466	0.450	0.425
Non-announcement days, mean	0.502	0.474	0.453	0.478	0.381
Ratio of means	1.168	1.310	1.030	0.941	1.114
t-statistic, *p*-value	0.506	0.069	0.809	0.542	0.373
Kruskal-Wallis test, *p*-value	0.522	0.118	0.905	0.638	0.289
Panel 2: Large surprise announcements					
Announcement days, mean	0.531	0.550	0.461	0.538	0.367
Non-announcement days, mean	0.502	0.474	0.453	0.478	0.381
Ratio of means	1.056	1.161	1.018	1.124	0.962
t-statistic, *p*-value	0.880	0.565	0.932	0.459	0.857
Kruskal-Wallis test, *p*-value	0.915	0.667	0.912	0.412	0.892
Panel 3: Small surprise announcements					
Announcement days, mean	0.611	0.648	0.468	0.420	0.448
Non-announcement days, mean	0.502	0.474	0.453	0.478	0.381
Ratio of means	1.217	1.369	1.034	0.878	1.176
t-statistic, *p*-value	0.443	0.054	0.805	0.260	0.222
Kruskal-Wallis test, *p*-value	0.439	0.088	0.929	0.320	0.158
Panel 4: Large vs. small surprise announcements					
Large announcement days, mean	0.531	0.550	0.461	0.538	0.367
Small announcement days, mean	0.611	0.648	0.468	0.420	0.448
Ratio of means	0.868	0.848	0.984	1.280	0.818
t-statistic, *p*-value	0.676	0.469	0.947	0.113	0.311
Kruskal-Wallis test, *p*-value	0.578	0.391	0.995	0.112	0.300

Panel 5: Auctions					
30 minutes ending at:	**11:30**	**12:00**	**12:30**	**13:00**	**13:30**
Announcement days, mean	0.316	0.457	0.544	0.423	0.332
Non-announcement days, mean	0.419	0.426	0.444	0.427	0.437
Ratio of means	0.755	1.073	1.226	0.993	0.761
t-statistic, *p*-value	0.186	0.713	0.286	0.974	0.289
Kruskal-Wallis test, *p*-value	0.231	0.682	0.292	0.962	0.373
Workup 1: proportion of total trades that have undergone size expansion in interval					

Table 10: 2-Year Benchmark, Workup 2

30 minutes ending at:	8:00	8:30	9:00	9:30	10:00
Panel 1: All announcements					
Announcement days, mean	0.680	0.683	0.613	0.633	0.605
Non-announcement days, mean	0.615	0.540	0.572	0.640	0.517
Ratio of means	1.107	1.264	1.073	0.988	1.169
t-statistic, *p*-value	0.621	0.087	0.509	0.886	0.142
Kruskal-Wallis test, *p*-value	0.741	0.185	0.365	0.360	0.370
Panel 2: Large surprise announcements					
Announcement days, mean	0.606	0.641	0.659	0.767	0.536
Non-announcement days, mean	0.615	0.540	0.572	0.640	0.517
Ratio of means	0.986	1.188	1.154	1.198	1.035
t-statistic, *p*-value	0.965	0.461	0.404	0.143	0.850
Kruskal-Wallis test, *p*-value	0.751	0.719	0.503	0.354	0.886
Panel 3: Small surprise announcements					
Announcement days, mean	0.713	0.699	0.599	0.587	0.633
Non-announcement days, mean	0.615	0.540	0.572	0.640	0.517
Ratio of means	1.160	1.295	1.048	0.917	1.223
t-statistic, *p*-value	0.508	0.089	0.687	0.359	0.083
Kruskal-Wallis test, *p*-value	0.536	0.146	0.446	0.111	0.226
Panel 4: Large vs. small surprise announcements					
Large announcement days, mean	0.606	0.641	0.659	0.767	0.536
Small announcement days, mean	0.713	0.699	0.599	0.587	0.633
Ratio of means	0.850	0.917	1.100	1.306	0.846
t-statistic, *p*-value	0.592	0.683	0.623	0.035	0.320
Kruskal-Wallis test, *p*-value	0.348	0.443	0.958	0.027	0.344
Panel 5: Auctions					
30 minutes ending at:	**11:30**	**12:00**	**12:30**	**13:00**	**13:30**
Announcement days, mean	0.599	0.602	0.694	0.541	0.468
Non-announcement days, mean	0.569	0.545	0.566	0.530	0.530
Ratio of means	1.053	1.104	1.226	1.022	0.884
t-statistic, *p*-value	0.744	0.549	0.225	0.912	0.576
Kruskal-Wallis test, *p*-value	0.786	0.653	0.307	0.949	0.340

Workup 2: the proportion of total trading volume from trades that have undergone size expansion in interval

Table 11: 2-Year Benchmark, Bid/Ask Spread

5 minutes ending at:	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
Panel 1: All announcements												
Announcement days, mean	1.396	1.454	1.277	1.313	1.236	2.007	1.789	1.479	1.222	1.202	1.330	1.249
Non-announcement days, mean	1.492	1.477	1.415	1.465	1.409	1.425	1.586	1.362	1.198	1.210	1.222	1.226
Ratio of means	0.936	0.984	0.903	0.896	0.877	1.409	1.128	1.086	1.020	0.993	1.089	1.019
t-statistic, *p*-value	0.467	0.842	0.240	0.220	0.123	0.005	0.190	0.341	0.814	0.944	0.441	0.861
Kruskal-Wallis test, *p*-value	0.894	0.974	0.554	0.109	0.225	0.037	0.040	0.198	0.745	0.442	0.106	0.711
Panel 2: Large surprise announcements												
Announcement days, mean	1.463	1.413	1.397	1.509	1.239	1.655	1.716	1.287	1.344	1.178	1.477	1.314
Non-announcement days, mean	1.492	1.477	1.415	1.465	1.409	1.425	1.586	1.362	1.198	1.210	1.222	1.226
Ratio of means	0.980	0.957	0.988	1.030	0.879	1.161	1.082	0.945	1.122	0.974	1.209	1.072
t-statistic, *p*-value	0.903	0.746	0.931	0.835	0.363	0.504	0.622	0.687	0.395	0.867	0.268	0.689
Kruskal-Wallis test, *p*-value	0.589	0.835	0.508	0.934	0.827	0.622	0.257	0.712	0.236	0.751	0.075	0.829
Panel 3: Small surprise announcements												
Announcement days, mean	1.374	1.468	1.234	1.239	1.235	2.139	1.815	1.555	1.184	1.211	1.280	1.228
Non-announcement days, mean	1.492	1.477	1.415	1.465	1.409	1.425	1.586	1.362	1.198	1.210	1.222	1.226
Ratio of means	0.921	0.994	0.872	0.846	0.877	1.502	1.144	1.142	0.989	1.001	1.048	1.002
t-statistic, *p*-value	0.422	0.946	0.170	0.085	0.175	0.003	0.189	0.175	0.905	0.995	0.712	0.987
Kruskal-Wallis test, *p*-value	0.659	0.879	0.277	0.053	0.167	0.027	0.056	0.163	0.843	0.437	0.289	0.736
Panel 4: Large vs. small surprise announcements												
Large announcement days, mean	1.463	1.413	1.397	1.509	1.239	1.655	1.716	1.287	1.344	1.178	1.477	1.314
Small announcement days, mean	1.374	1.468	1.234	1.239	1.235	2.139	1.815	1.555	1.184	1.211	1.280	1.228
Ratio of means	1.065	0.963	1.133	1.217	1.003	0.773	0.946	0.827	1.135	0.973	1.154	1.070
t-statistic, *p*-value	0.636	0.776	0.347	0.231	0.983	0.379	0.694	0.238	0.442	0.858	0.415	0.731
Kruskal-Wallis test, *p*-value	0.364	0.804	0.198	0.253	0.590	0.302	0.718	0.488	0.177	0.938	0.311	0.992
Panel 5: Auctions												
5 minutes ending at:	**12:20**	**12:25**	**12:30**	**12:35**	**12:40**	**12:45**	**12:50**	**12:55**	**13:00**	**13:05**	**13:10**	**13:15**
Auction days, mean	1.125	1.028	1.216	1.290	1.674	1.420	1.669	1.623	1.212	1.129	1.338	1.657
Non-auction days, mean	1.479	1.432	1.385	1.445	1.449	1.407	1.420	1.406	1.331	1.355	1.339	1.344
Ratio of means	0.761	0.718	0.878	0.893	1.155	1.009	1.176	1.154	0.910	0.833	0.999	1.233
t-statistic, *p*-value	0.371	0.296	0.675	0.697	0.575	0.977	0.534	0.553	0.731	0.563	0.997	0.406
Kruskal-Wallis test, *p*-value	0.155	0.021	0.337	0.837	0.091	0.329	0.094	0.033	0.875	0.570	0.854	0.437

Bid/ask spread: the average difference between the best bid and offer prices in each time interval

Table 12: 2-Year Benchmark, Kyle 1

30 minutes ending at:	8:00	8:30	9:00	9:30	10:00
Panel 1: All announcements					
Announcement days, coef.	0.508	0.614	0.132	0.632	0.191
p-value	0.000	0.035	0.362	0.000	0.016
Non-announcement days, coef.	0.732	0.426	0.553	0.342	0.565
p-value	0.000	0.111	0.000	0.000	0.000
p-value, F-stat, diff. in slope	0.116	0.550	0.020	0.002	0.002
Panel 2: Large surprise announcements					
Announcement days, coef.	0.507	-0.193	1.477	0.336	0.332
p-value	0.000	0.573	0.075	0.004	0.000
Non-Announcement days, coef.	0.732	0.426	0.553	0.342	0.565
p-value	0.000	0.111	0.000	0.000	0.000
p-value, F-stat, diff. in slope	0.164	0.879	0.096	0.339	0.228
Panel 3: Small surprise announcements					
Announcement days, coef.	0.492	0.607	-0.116	0.751	0.317
p-value	0.003	0.044	0.677	0.000	0.000
Non-announcement days, coef.	0.732	0.426	0.553	0.342	0.565
p-value	0.000	0.111	0.000	0.000	0.000
p-value, F-stat, diff. in slope	0.186	0.470	0.011	0.000	0.089
Panel 4: Large vs. small surprise announcements					
Large announcement days, coef.	0.507	-0.193	1.477	0.336	0.332
p-value	0.000	0.573	0.075	0.004	0.000
Small announcement days, coef.	0.492	0.607	-0.116	0.751	0.317
p-value	0.003	0.044	0.677	0.000	0.000
p-value, F-stat, diff. in slope	0.437	0.016	0.110	0.026	0.923

Panel 5: Auctions					
30 minutes ending at:	**11:30**	**12:00**	**12:30**	**13:00**	**13:30**
Auction days, coef.	0.298	0.446	0.988	1.020	0.309
p-value	0.022	0.003	0.009	0.003	0.000
Non-auction days, coef.	0.542	0.410	0.603	0.442	-3.417
p-value	0.000	0.000	0.000	0.000	0.805
p-value, F-stat, diff. in slope	0.059	0.229	0.005	0.004	0.608

Kyle 1: estimate price impact by regressing log changes in price on net trading activity over interval. Net trading activity is the volume of buyer-initiated trades minus the number of seller-initiated trades over the interval.

Table 13: 2-Year Benchmark, Kyle 2

30 minutes ending at:	8:00	8:30	9:00	9:30	10:00
Panel 1: All announcements					
Announcement days, coef.	0.010	0.001	0.010	0.024	0.006
p-value	0.003	0.397	0.161	0.002	0.051
Non-announcement days, coef.	0.017	0.018	0.020	0.010	0.020
p-value	0.000	0.139	0.002	0.002	0.040
p-value, F-stat, diff. in slope	0.351	0.559	0.151	0.017	0.061
Panel 2: Large surprise announcements					
Announcement days, coef.	0.028	0.016	0.073	0.011	0.005
p-value	0.027	0.030	0.001	0.013	0.258
Non-announcement days, coef.	0.017	0.018	0.020	0.010	0.020
p-value	0.000	0.139	0.002	0.002	0.040
p-value, F-stat, diff. in slope	0.381	0.856	0.051	0.262	0.441
Panel 3: Small surprise announcements					
Announcement days, coef.	0.008	-0.002	0.005	0.031	0.010
p-value	0.002	0.529	0.291	0.007	0.004
Non-announcement days, coef.	0.017	0.018	0.020	0.010	0.020
p-value	0.000	0.139	0.002	0.002	0.040
p-value, F-stat, diff. in slope	0.205	0.461	0.099	0.002	0.257
Panel 4: Large vs. small surprise announcements					
Large announcement days, coef.	0.028	0.016	0.073	0.011	0.005
p-value	0.027	0.030	0.001	0.013	0.258
Small announcement days, coef.	0.008	-0.002	0.005	0.031	0.010
p-value	0.002	0.529	0.291	0.007	0.004
p-value, F-stat, diff. in slope	0.104	0.010	0.033	0.039	0.561

Panel 5: Auctions					
30 minutes ending at:	**11:30**	**12:00**	**12:30**	**13:00**	**13:30**
Auction days, coef.	0.008	0.014	0.023	0.061	0.025
p-value	0.152	0.111	0.034	0.023	0.000
Non-auction days, coef.	0.014	0.014	0.032	0.015	-0.092
p-value	0.000	0.000	0.000	0.001	0.782
p-value, F-stat, diff. in slope	0.005	0.164	0.007	0.002	0.717

Kyle 2: estimate price impact by regressing log changes in price on net trading activity over interval. Net trading activity is the number of buyer-initiated trades minus the number of seller-initiated trades over the interval.

Figure 1: 8:30 a.m. Announcement, 2-Year Benchmark, CAAR*

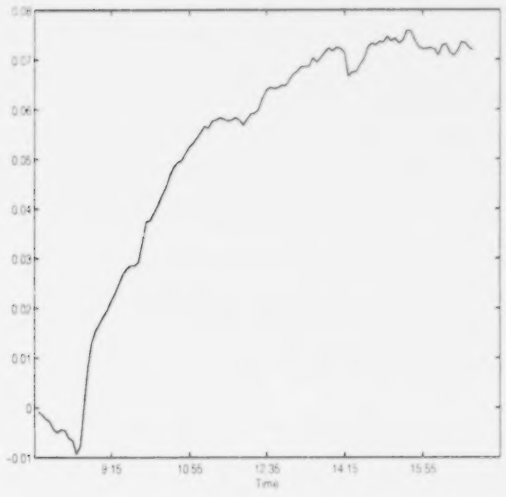


Figure 2: 8:30 a.m. Announcement, 5-Year Benchmark, CAAR*

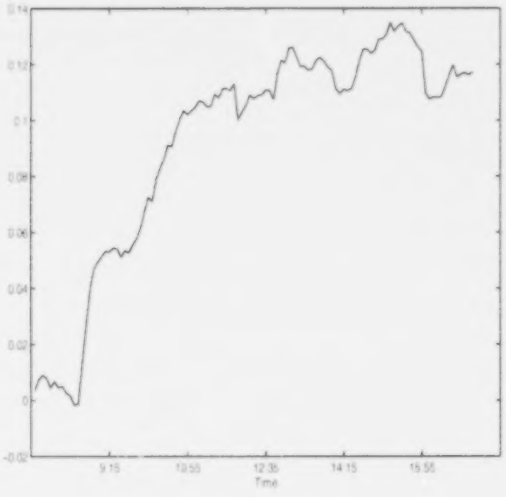


Figure 3: 8:30 a.m. Announcement, 10-Year Benchmark, CAAR*

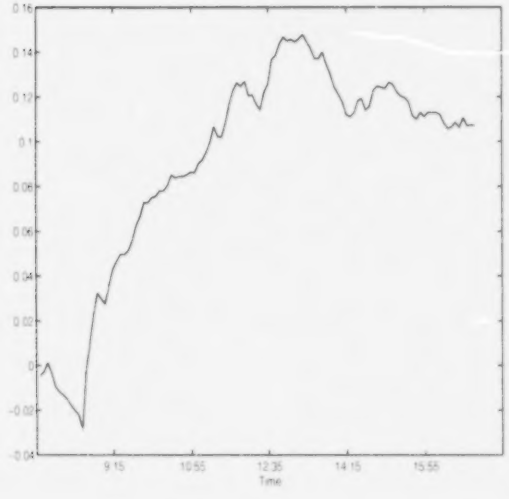
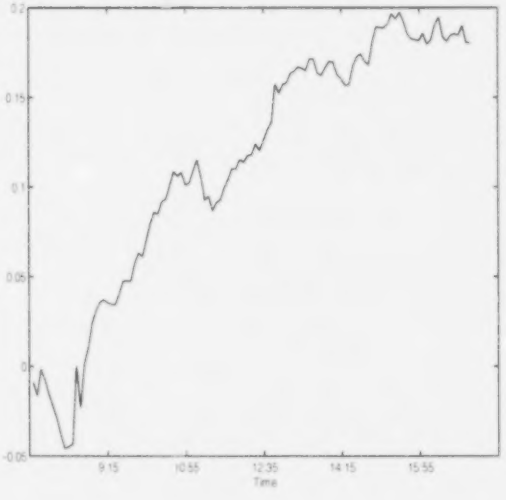


Figure 4: 8:30 a.m. Announcement, 30-Year Benchmark, CAAR*



* Cumulative absolute average returns (CAAR) are calculated by subtracting the absolute return in each 5-minute interval on non-event days from the absolute return on event days. Results are plotted cumulatively throughout the day.

Figure 5: Bond Auction, 2-Year Benchmark, CAAR*

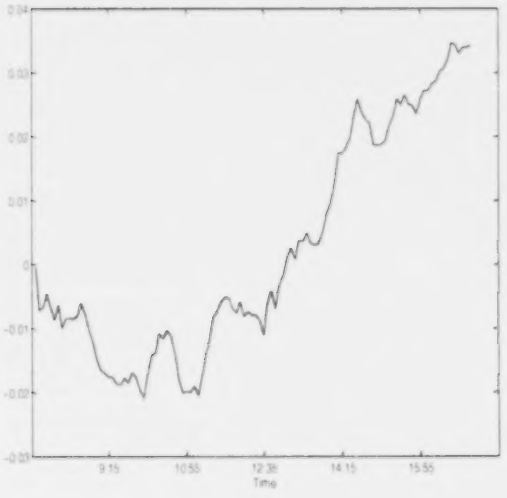


Figure 6: Bond Auction, 5-Year Benchmark, CAAR*

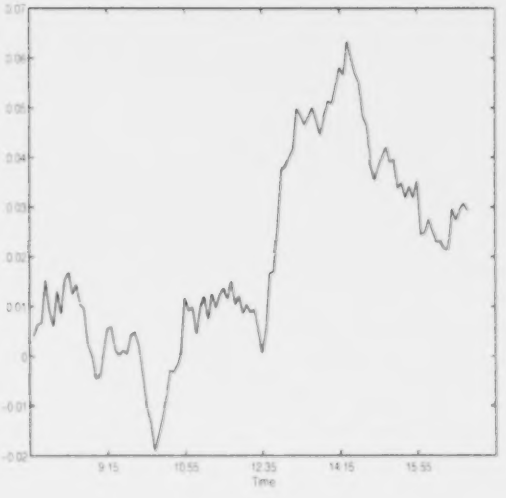


Figure 7: Bond Auction, 10-Year Benchmark, CAAR*

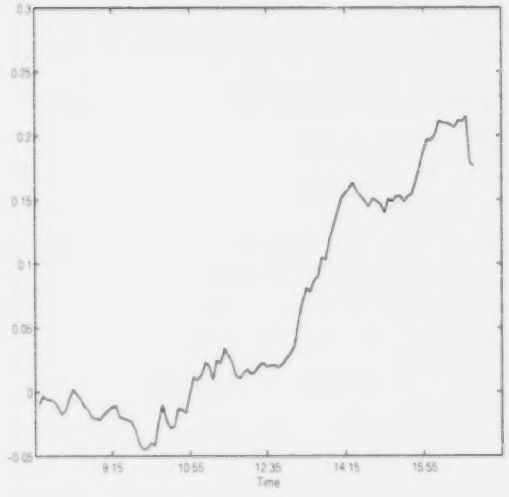
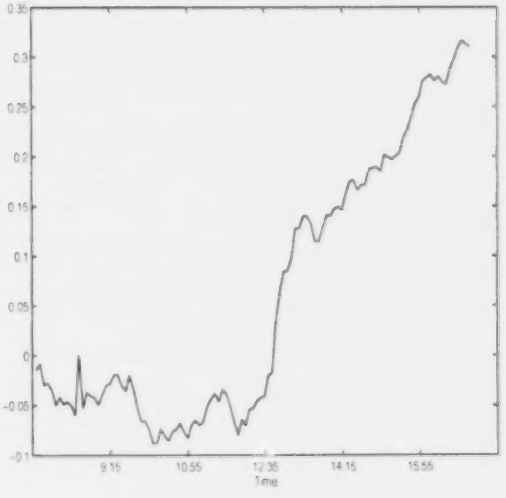


Figure 8: Bond Auction, 30-Year Benchmark, CAAR*



* Cumulative absolute average returns (CAAR) are calculated by subtracting the absolute return in each 5-minute interval on non-event days from the absolute return on event days. Results are plotted cumulatively throughout the day.

Figure 9: 8:30 a.m. Announcement, 2-Year Benchmark, Trading Volume

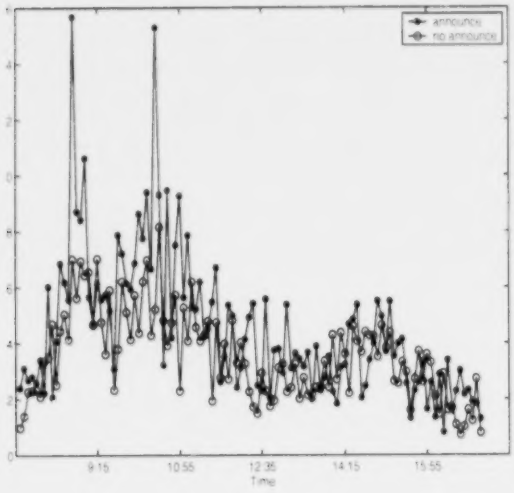


Figure 10: 8:30 a.m. Announcement, 2-Year Benchmark, Bid/Ask Spread

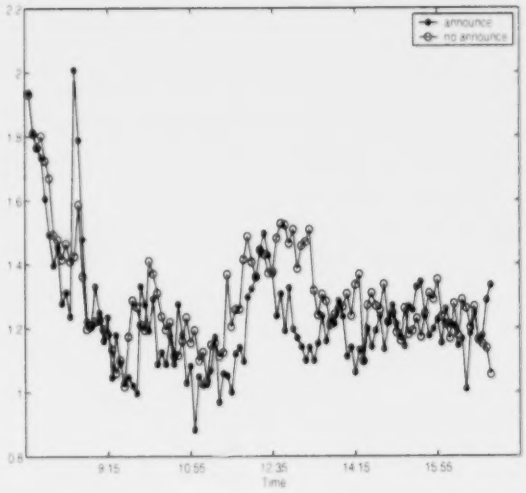


Figure 11: 8:30 a.m. Announcement, 2-Year Benchmark, Trade Frequency

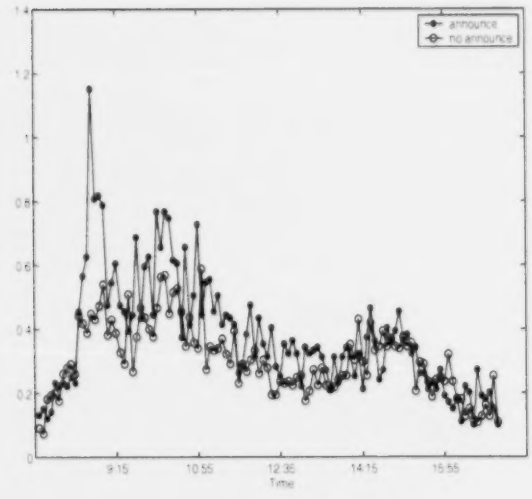


Figure 12: 8:30 a.m. Announcement, 2-Year Benchmark, Quote Frequency

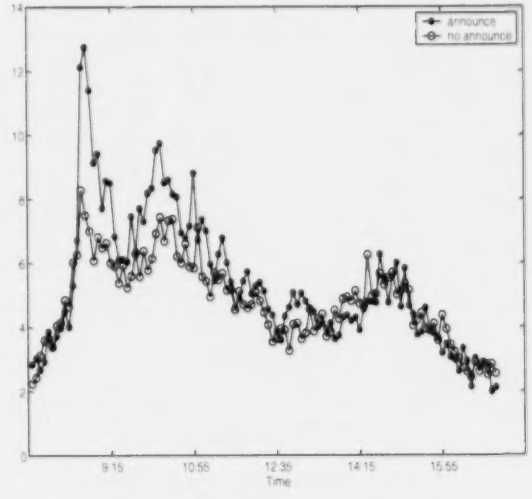


Figure 13: 8:30 a.m. Announcement, 2-Year Benchmark, Bid Size

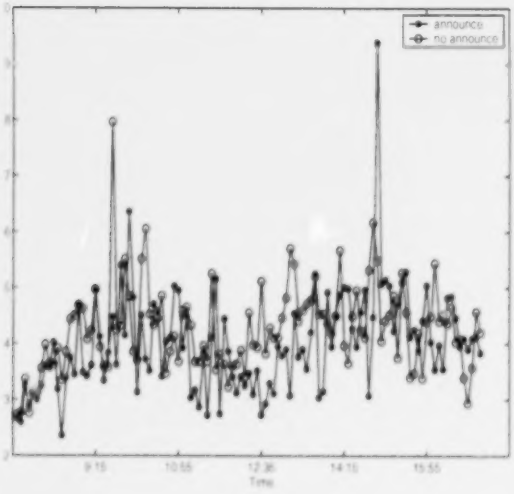


Figure 14: 8:30 a.m. Announcement, 2-Year Benchmark, Ask Size

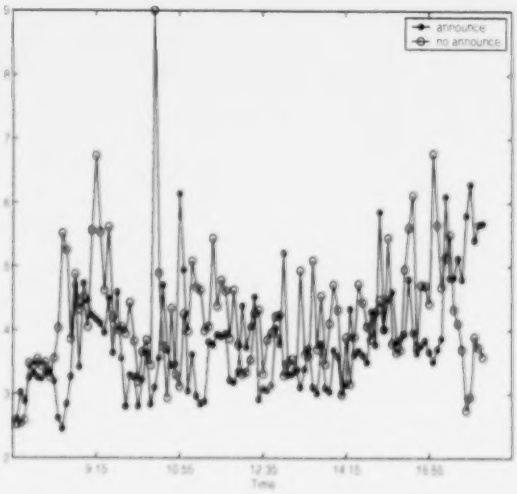


Figure 15: Bond Auction, 2-Year Benchmark, Trading Volume

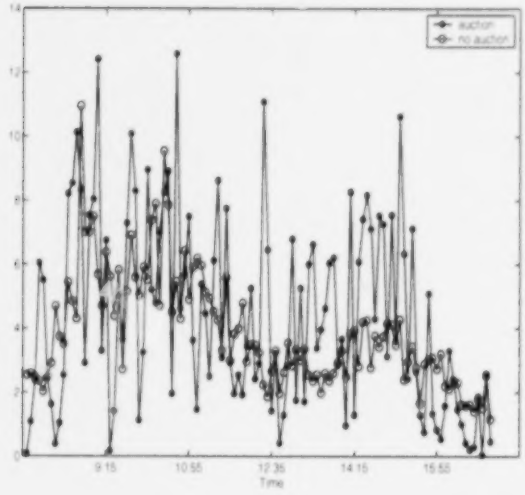


Figure 16: Bond Auction, 2-Year Benchmark, Bid/Ask Spread

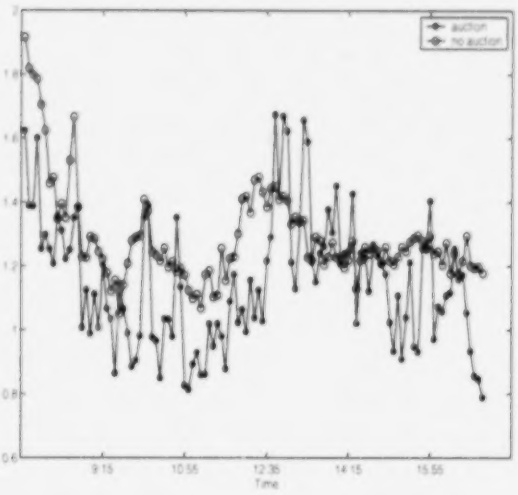


Figure 17: Bond Auction, 2-Year Benchmark, Trade Frequency

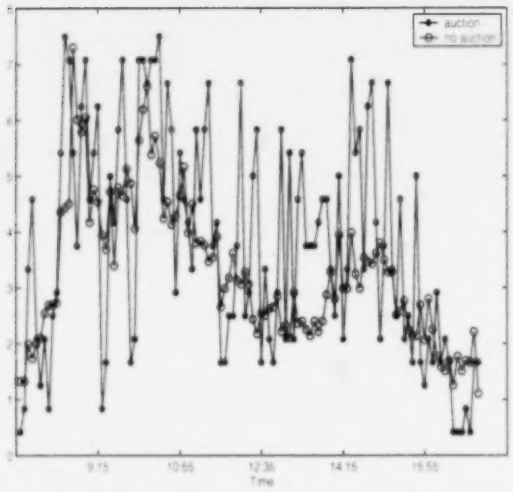


Figure 18: Bond Auction, 2-Year Benchmark, Quote Frequency

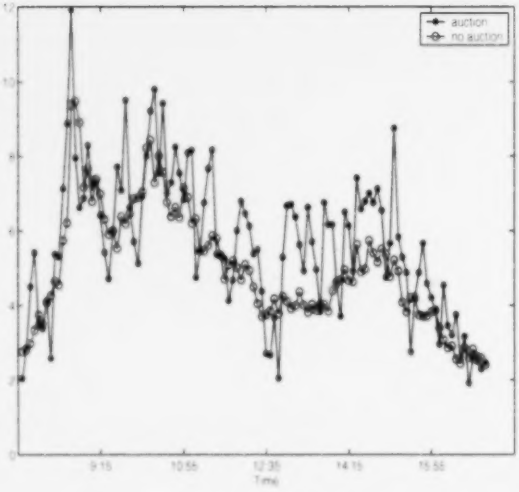


Figure 19: Bond Auction, 2-Year Benchmark, Bid Size

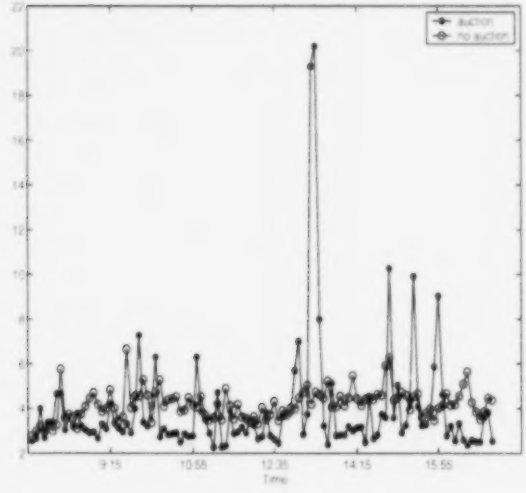
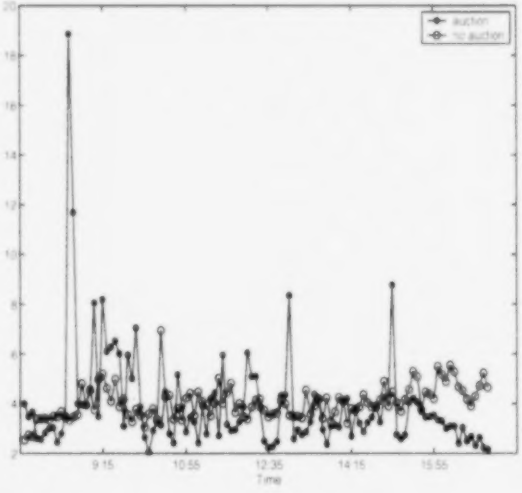


Figure 20: Bond Auction, 2-Year Benchmark, Ask Size



Appendix

A.1 Statistical Tests

A normal distribution with variance σ^2 has a third central moment (skewness) that is zero, and a fourth central moment (kurtosis) that is $3\sigma^4$. To test whether the distribution of a variable is normal, an LM statistic is constructed (see Davidson and MacKinnon 1993):

$$LM = (6n)^{-\frac{1}{2}} \sum_{t=1}^{n} e_t^3 + (24n)^{-\frac{1}{2}} \sum_{t=1}^{n} (e_t^4 - 3), \tag{A1}$$

where normalized observations are calculated as

$$e_t = \frac{u_t - \hat{\mu}}{\hat{\sigma}}. \tag{A2}$$

The LM statistic is distributed $\chi^2(2)$.

Brown-Forsythe-modified Levene F-statistics are calculated as

$$F = \left[\frac{\sum_{j=1}^{2} m_j (X_i - \bar{X})^2}{\sum_{j=1}^{2} \left(\sum_{i=1}^{m_j} (X_{ij} - X_i)^2 \right)} \right] \times \left[\frac{N-2}{2-1} \right], \tag{A3}$$

where

$$X_{ij} = \left| R_{ij} - \bar{R} \right| \qquad X_i = \sum_{i=1}^{m_j} \frac{X_{ij}}{m_j} \qquad \bar{X} = \sum_{j=1}^{2} \sum_{i=1}^{m_j} \frac{X_{ij}}{N} \qquad N = \sum_{j=1}^{2} m_j, \tag{A4}$$

and R_{ij} is the return for day i and interval j, $\bar{R}$ is the sample median; m_j is the number of observations in the sample of interval j. Brown-Forsythe-modified Levene F-statistics are calculated to compare variances in returns on days with and without macroeconomic news announcements and securities auctions. Under the null hypothesis of homoscedasticity across sample groups, the statistic is distributed as $F(1, N-2)$. The test is robust against departures from normality, and does not require equal sample sizes. It uses the absolute deviation of the

observations in each sample from the sample median, and then evaluates whether the means of these deviations are equal for all samples.

The Kruskal-Wallis test is a non-parametric test for comparing the means of two series. More specifically, it is used to test whether there is a statistically significant difference between the means of two series, such as bid/ask spreads on event and non-event days. The test statistic is

$$KW = \frac{12}{N(N+1)} \sum_{j=1}^{J} \frac{S_j^2}{m_j} - 3(N+1), \tag{A5}$$

where J is the number of series (equal to 2: event and non-event series); N is the total number of observations from both series combined; m_j is the number of observations from series j; and S_j is the ranksum for series j. The test statistic is distributed $\chi^2(J-1)$ under the null hypothesis of equal medians. If the p-value for the null hypothesis that all samples are drawn from the same population (or from different populations with the same mean) is near zero, this suggests that at least one sample mean is significantly different from the other sample mean. One of the advantages of non-parametric procedures is that they are not severely affected by changes in a small proportion of the data (such as the inclusion of an extreme event).

After estimating the price impacts of signed trades and volumes using equation (1), an F-statistic testing the restriction that the slope coefficients in the two samples are the same is calculated:

$$\left[\frac{(\hat{e}'\hat{e} - (e_1'\hat{e}_1 + \hat{e}_2'\hat{e}_2))}{(\hat{e}_1'\hat{e}_1 + \hat{e}_2'\hat{e}_2)}\right] \sim F(1, T_1 + T_2 - 2K), \tag{A6}$$

where $i = 1, 2$, and $\hat{e} = (y - X\hat{\beta})$, calculated from a regression on the pooled results, T_i is the sample size of sample i, and K is equal to the number of regressors.

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